Bandwidth characteristics of folded structures with very small normal-mode helical antennas

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1. Introduction

Recently, very small antennas are requested in RFID tags and tire attached sensors of the tire pressure monitoring system (TPMS). In these applications, normal-mode helical antennas (NMHA) are interested that can achieve high antenna efficiencies at very small size such as 1/100 wavelengths. Moreover, NMHA can increase antenna gains in the metal plate proximity use. However, NMHA have serious defect of very narrow bandwidths in very small sizes. In order to expand bandwidths, employing additional antennas are often considered.

In this paper, employment of folded structures with NMHA is studied. In studying antenna electrical characteristics, electromagnetic simulations are conducted. As for folded structures, antenna input impedances increases of NMHA were studied [1]. However, effects on bandwidths were not shown. Therefore, band widths characteristics of a fundamental NMHA is studied at first. Then, calculated results of folded structures are shown.

2. Fundamental antenna characteristics

Antenna structural parameters of the NMHA is shown in Fig.1. The most important condition for efficient radiations of a NMHA is the self-resonant condition. Self-resonant structures are determined by the following equation [2]. Antenna structures of Eq. (1) and simulation are shown in Fig.2. Relations of antenna length (H_A) and diameter (D_A) are determined for a given parameter of number of terns (N).

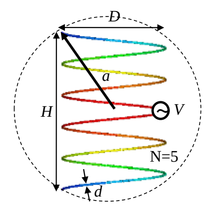


Fig.1 Structure of NMHA

$$600\pi \frac{19.7N\left(\frac{D}{\lambda}\right)^2}{9\frac{D}{\lambda}+20\frac{H}{\lambda}} = \frac{279\frac{H}{\lambda}}{N\pi\left(0.92\frac{H}{\lambda}+\frac{D}{\lambda}\right)^2} \qquad (1)$$

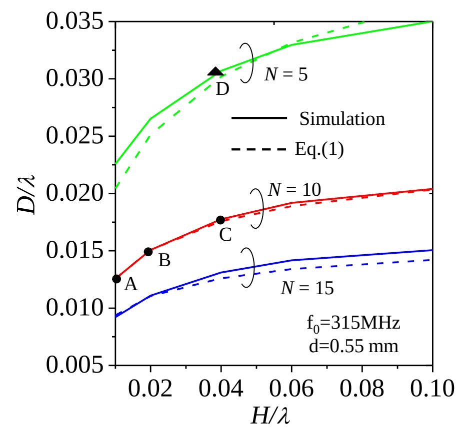


Fig.2 Self-resonant structures

At the self-resonant structures, bandwidths are shown by following expressions [3]. First of all, the fractional bandwidth (FBW) is given by the equation..

$$FBW(\omega_0) = \frac{\omega_u(s) - \omega_l(s)}{\omega_0} \qquad (2)$$

Here, ω_0 indicates center frequency. $\omega_u(s)$ and $\omega_l(s)$ indicate upper and lower frequencies. s indicates the VSWR value. Next, Q factor is given by the next equation.

$$Q(\omega_0) = \frac{2\sqrt{\beta}}{FBW(\omega_0)} \quad , \quad \sqrt{\beta} = \frac{s-1}{2\sqrt{s}} \qquad (3)$$

On the other hand, smallest antenna Q_{lb} is given by the next expression.

$$Q_{lb} = \frac{1}{(ka)^3} + \frac{1}{ka} \qquad (4)$$

Here, a indicates a radius of the sphere enclosing an antenna as shown in Fig.1. Comparisons of Q_{lb} and Q of NMHA are shown in Fig. 3. $Q(\omega_0)$ are obtained at structures of A, B and C that are shown in Fig.2. As for VSWR, s = 2 is selected.

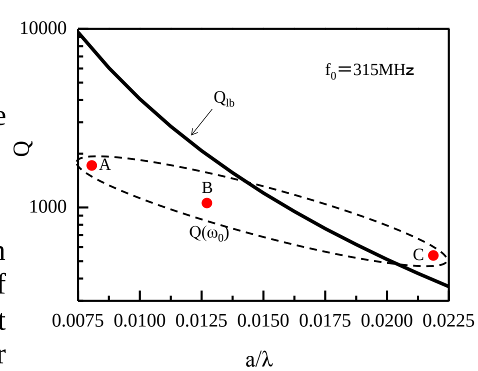


Fig.3 Q factors compared with Chu limit

$Q(\omega_0)$ of A and B becomes smaller than Q_{lb}. The cause of small Q values is owing to the ohmic loss of NMHA. However, Q values of exceeding 1,000 are still very large.

3. Band width characteristics of folded structures

The folded structure is shown in Fig. 4. The antenna structure of D shown in Fig.1 is used. This case, wire diameter is set to d =1 mm. The feed and parasitic antennas have the resonant frequencies of f_0 and $f_0+\Delta f$, respectively. VSWR characteristics of single and folded NMHA are shown in Fig.5. In Fi5(a), bandwidth at VSWR=2 is 0.47MHz. This corresponds to Q = 470. The result of Fig. 5(b) shows the case of a folded structure. The bandwidth at VSWR=2 becomes 0.81MHz. Although, Δf was change from zero to 0.5 MHz, achieved bandwidths could not change. By employing the folded structure, bandwidth is expanded approximately 1.7 times.

The input impedances of single and folded NMHA are shown in Fig.6. The input resistance at the resonance is increased approximately 4 times. This increase agree very well with the theoretical value.

As a result, it is shown that the folded structure is useful in expanding bandwidth and input resistance increase. However, only the fundamental effect of the folded structure is understand in this study. Further studies of folded structures are necessary.

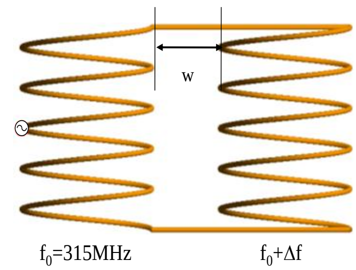
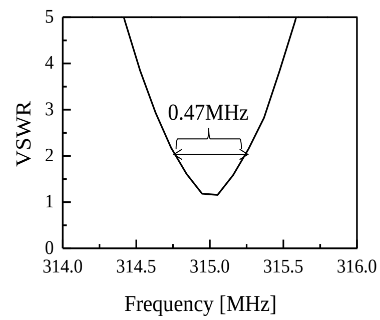
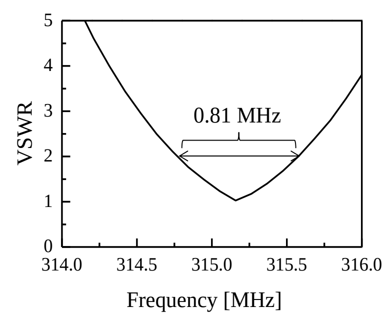


Fig.4 Folded structure



(a) Single NMHA



(b) Folded NMHA

Fig.5 Bandwidth characteristics

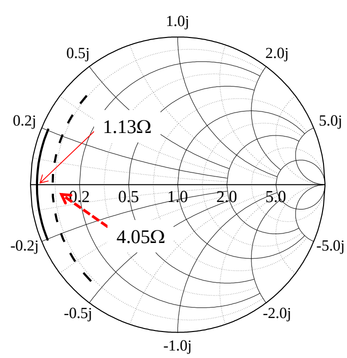


Fig.6 Input impedances

4. Conclusion

The effect of folded structure for expanding bandwidth is shown. Further studies are necessary to clarify the abilities of folded structures.

References

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